# Loads on Entrance Platforms for Offshore Wind Turbines

# LOADS ON ENTRANCE PLATFORMS FOR OFFSHORE WIND TURBINES

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The present paper gives an overview of the performed large scale tests in GWK, Hannover for studying wave run-up generated forces on wind turbine entrance platforms. The run-up height and velocity was measured by use of high speed video recordings supplemented by some wave gauges mounted at the pile. Hereafter, the run-up generated impact forces were measured on two types of grates and a solid plate. The pressure distribution was also measured for the solid plate. In addition to this the wave generated backfilling of an initial scour hole and the strength of the backfilling soil was studied. The purpose of all the tests was to study scale effects related to the above items by comparison with small scale tests and also to present new guidelines for design.

## 1. INTRODUCTION

If wind turbines are placed in an area with risk of sea ice, an ice cone is typically applied to break the ice by bending which significantly reduce the horizontal force from the ice. The ice cone provides also a platform with access to the wind turbine. In case there is no risk of sea ice a platform consisting of closed plates or gratings has typically been applied. Such platforms using gratings have previously been used for the large wind turbine farm Horns Reef 1 in Denmark. Fig. 1 shows two pictures of wave run-up on one of the wind turbine foundations in this farm for $H_{m0} \approx 2.5$ m, while the platform level is 9.0 m above SWL. Actual run-up values are much higher than expected or accounted for in the design. The platform was made of fiber grates and was thrown out from the support. In some cases, the support was removed as well.

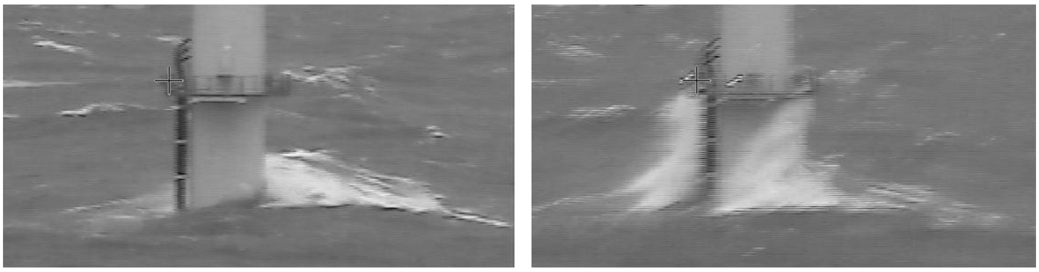

Fig. 1: Image of impact against entrance platform at Horns Reef 1.

The damages led to a small scale hydraulic model test study at Aalborg University (AAU) where wave run-up (De Vos et al., 2007 ; Lykke Andersen et al., 2006a) and the slamming forces generated on a solid horizontal platform and a cone were studied (Lykke Andersen et al., 2006b; 2007a) . Moreover, the drag coefficients were studied to give a force reduction factor for different types of grates (Lykke Andersen et al., 2007b).

## 2. AIM OF STUDY IN GWK

The aims of the large scale tests were to:

- Study scale effects on run-up on slender piles by comparing results from GWK and AAU;
- Study scale effects related to impact pressures and forces on a closed plate platform by comparing results from GWK and AAU;
- Study slamming forces on grates which is impossible to study in small scale wave flume tests. Compare slamming reduction factors with drag coefficient reduction factors found in experiments at AAU;
- Study scale effects related to the time scale of the back-filling of an initial deep scour hole;
- Study soil strength of back-filling which is of great important for fatigue calculation of piles designed without scour protection;
- Give design guidelines for above topics.

## 3. PRELIMINARY RESULTS

The observation from small scale tests that breaking waves give much higher run-ups and higher loads than non-breaking waves were verified in large scale. Actually the process is very sensitive to the breaking point. To get maximum run-up and force on the platform the wave needs to break just before the pile or directly on the pile. This also shows that the irregular wave kinematics are extremely important in order to correctly estimate wave run-up.

Design guidelines are currently based on small scale test results, which are not significantly different from the results of large scale tests. However, it is expected that the design guidelines can be improved by more detailed consideration of the wave kinematics in both breaking and close to breaking irregular waves.

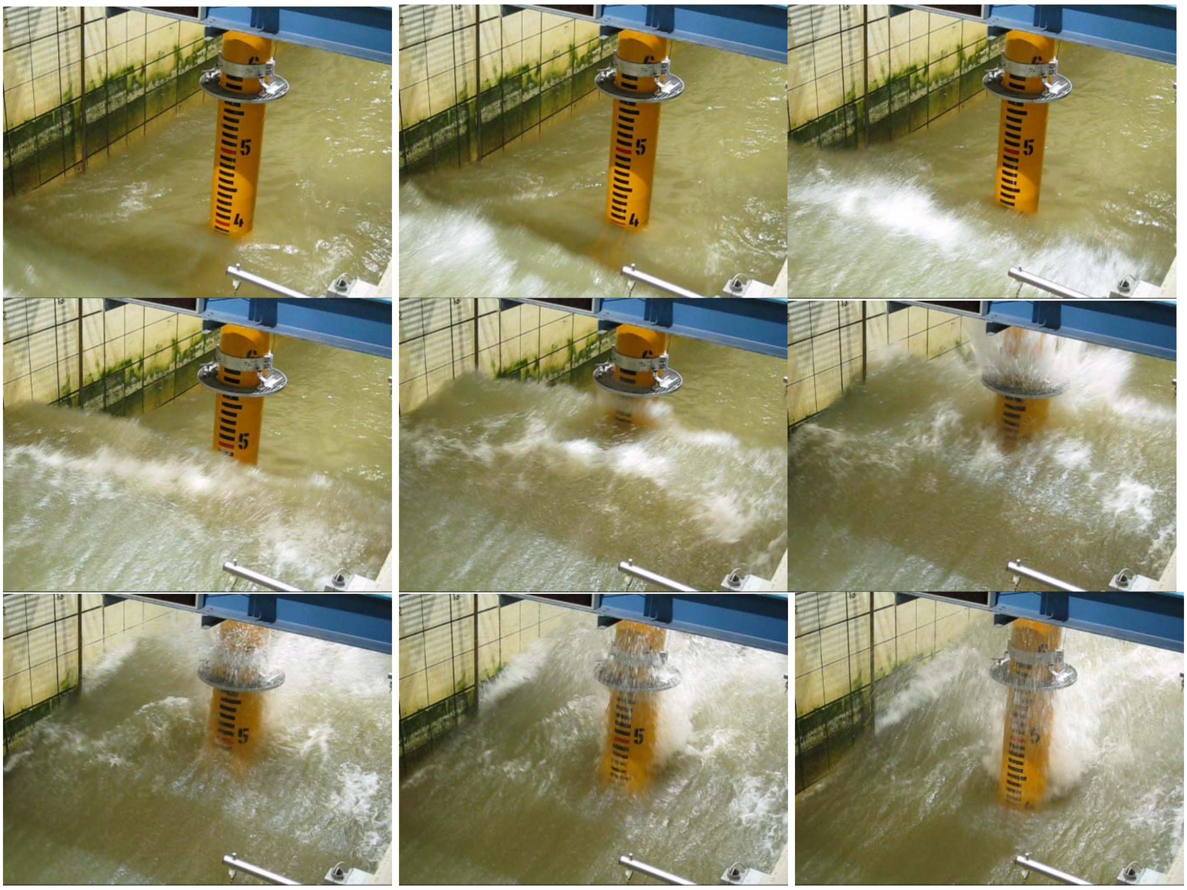

Fig. 2: Pictures ($\Delta t = 0.20$ s) of impacting irregular wave on grate platform (porosity 80%) at level +1.75.
Maximum load 0.51 kN for $h = 3$ m, $H_{m0} = 1.0$ m and $T_p = 5.9$ s, all values in model scale.

Fig. 3: Pictures ($\Delta t$ = 0.08 s) of impacting irregular wave on grate platform (porosity 60%) at level +1.75.
Maximum load 1.05 kN for $h$ = 3 m, $H_{m0}$ = 1.0 m and $T_p$ = 5.9 s, all values in model scale.

Freak waves and irregular waves were tested for run-up and load measurements with identical paddle steering signals in the two cases. Thus interrelated values of run-up and loads are available. Figs. 2-4 shows a comparison of the event giving the maximum force on the three types of platforms for identical steering signal corresponding to $H_{m0}$ = 1.0 m and $T_p$ = 5.9 s at the pile. For this sea state there are five run-up events giving approximately the same run-up height. The measured green water thick run-up reached approximately +1.8 m for these five events with spray up to at least level +3.0 m. The run-up formulae by Lykke Andersen et al., 2006a based on small scale results give for this wave a run-up height of 2.7 m and is thus in quite good agreement with the measurements. Figs. 2 and 3 refer to the same wave while for the closed platform (Fig. 4) the maximum force occurs for another of the waves in the series giving large run-up.  In both cases the individual wave height is more or less identical with $H_{max} \approx 1.6$ m.

By comparing Figs. 2-4 it is evident that the solid plate experiences significantly larger forces than the porous grates. The vertical loads seems to scale approximately with the solidity (1 – porosity), which was also found for drag by Lykke Andersen et al., 2007b. However, the vertical loads for all three platform types are very large, corresponding to approximately 0.5 to 2.5 MN in prototype.

The design formula of Lykke Andersen et al., 2007b based on small scale results give for the maximum wave a maximum vertical force of 2.2 kN on the closed platform which is also in very good agreement with the measured 2.3 kN.

The loads are typical church roof shaped with a short impulse followed by a longer duration quasi-static load and some vibrations of the structure. Therefore, the maximum force is not the only parameter to describe the loads, but the time history is also very important. Moreover, the response of the structure for such types of loads should be determined for design purposes in order to know if dynamic amplification or dampening occurs. Here it should be noted that the eigen frequency of the platform was 50-60 Hz in the model, which is expected to correlate quite well with prototype platforms of such types.

Fig. 4: Pictures ($\Delta t$ = 0.08 s) of impacting irregular wave on solid platform (porosity 0%) at level +1.75.
Maximum load 2.3 kN for $h$ = 3 m, $H_{m0}$ = 1.0 m and $T_p$ = 5.9 s, all values in model scale.

## ACKNOWLEDGEMENT

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